Mapping the benefits and costs associated with process innovation

Mapping the benefits and costs associated with process innovation: the case of RFID adoption

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Abstract

The successful implementation of any innovation requires an understanding of its benefits and costs. This study examines the changes in the magnitude of costs and benefits associated with technology process innovation adoption as the innovation diffuses across different industries. Using RFID as an exemplar technology, the study shows that the magnitude of benefits and costs associated with technological process innovation adoption within different industries varies as technology diffuses beyond early adopters to the early majority. During the early stages of technology evolution, the development cost, the cost of capital, ethical costs and simple direct implementation costs (in the form of the cost of tags) predominate. As a dominant design emerges the profile of costs changes with the emphasis on initiation costs, more holistic direct implementation costs, and indirect implementation costs. A similar change in the emphasis of benefits is observed, with a shift from direct to indirect benefits being noticeable as the technology moves from early adopters to early majority adopters. Our findings help to explain the difficulties in consistently measuring innovation outcomes observed in the innovation implementation literature, and emphasise the need to take into consideration the stage of technology development as a significant factor that influences the realised outcomes from innovation implementation.

Keywords: process innovation, innovation costs, innovation benefits; innovation implementation; innovation adoption; RFID

1. Introduction

The benefits and costs associated with the organizational adoption of technology innovation in general, and technology process innovation in particular, have been widely covered in the innovation literature. For example a wealth of research has considered the benefits (Chwelos et al., 2001; Cunningham and Tynan, 1993; Iacovou et al., 1995; Subramani, 2004) and, to a more limited extent, the costs (Premkumar et al., 1994; Zhu et al., 2004) associated with the adoption of information technology (IT) innovation in organizations, one of the most researched forms of process innovation (Tidd et al, 2005). Longitudinal studies of technology diffusion have also identified the role of innovation outcomes (in particular benefits and cost) in shaping technology diffusion. For example, Attewell (1992) notes the role that the cost of equipment plays in shaping the adoption of business computing.

The adoption of innovation in organisation can be seen as a stage process involving the *generation* of an innovative idea, the *acceptance* of that innovation represented by an organizational mandate to change, and its *implementation* so that the innovation becomes ingrained within the organization (Bunduchi and Smart, 2010; Thompson, 1965). Existing literature has examined the benefits and costs associated with innovation adoption either as antecedents of the decision to accept and/or to implement an innovation (e.g. Chwelos et al., 2001; Premkumar et al., 1994) or, less often, as the outcomes of successful or not so successful acceptance and/or implementation (e.g. Klein and Sorra, 1996; Meyers et al., 1999). One strand of literature - adoption studies – has focused on users' expectations of a particular innovation and the role that these expectations play in driving innovation adoption, concentrating particularly on the acceptance of innovations within an organization. A second strand - implementation studies – has emphasised the realised outcomes of innovation acceptance and implementation, and in particular the relationship between implementation success and innovation outcomes. While adoption studies have identified different types of anticipated benefits and, to lesser extent, anticipated costs (see Bunduchi and Smart, 2010), implementation studies have generally been vague in identifying the nature of innovation outcomes, and have instead highlighted the difficulty of assessing the precise nature of innovation benefits (Linton, 2002). Implementation literature has also recognized that the realisation of these benefits is dependent upon the "success" of innovation implementation (Klein and Sorra, 1996). These observations illustrate Weick's comment that "*we typically do a fine grained analysis to isolate separate causes but then do a coarse grained analysis when we examine effects*" (1974, pg. 366). Meyer and Goes (1988) also observed that the antecedents of innovation adoption, such as expected outcomes, were carefully identified and isolated in the literature, while realised outcomes were generally lumped together and treated as a single effect of implementation.

Drawing from the categories of benefits and costs identified in the adoption literature, our study contributes to the implementation literature by examining (1) the realised benefits and costs associated with the adoption of innovations; and (2) whether these innovation outcomes vary depending on the stage of technology development. This dynamic approach to the benefits and costs associated with innovation adoption over time is rare in the literature which, by and large, has examined these variables only at one particular point in time. This snapshot approach to examine innovation outcomes has been helpful in assessing the impact that benefits and costs have on the decision to adopt/accept a particular innovation at a particular point in time (adoption studies), and on what constitutes innovation (implementation) success. However, research to date has not attempted to examine how the magnitude of the different constituents of the benefit and cost variables changes with time. We propose that the changing magnitude of the benefits and costs associated with technology adoption represents one reason why, as Linton (2002) notes, implementation research to date has had difficulty in consistently measuring innovation implementation outcomes. For example, the costs and benefits associated with the implementation of an emergent technology in the early stages of its development may be very different from the cost and benefits incurred by organizations that implement the same technology once it has matured and become established within an industry.

This paper focuses on one particular type of innovation: technological process innovation. Process innovations are new ways of producing and/or delivering goods and services (Edquist et al., 2001; OECD, 2001; Tidd et al., 2005) and can be divided into two broad categories: technological and organizational process innovations. The term "technological process innovation" refers to new products (such as new information systems) that are used in the production process, while "organizational process innovations" (such as new management accounting methods) are new ways of organizing business activities (Edquist et al., 2001). However, in practice the distinction between technology and organizational process innovations if often blurred, as the introduction of many new technologies is accompanied by changes in the organization of business activities (Reichstein and Salter, 2006).

While the vast majority of technology process innovation adoption studies focus on firm level adoption (e.g. the adoption of e-business by European firms (Zhu et al, 2006)) or individual level adoption (e.g. the adoption of e-mail by employees (Davis, 1989)), we consider adoption at the level of the industry. In doing so, we draw upon longitudinal studies of technology development that have shown how radical new technologies often emerge in market niches or industry sectors. These niches/sectors act as incubators of a technology in the early stages of its development (van den Ende and Kemp, 1999); the technology then diffuses gradually to other sectors (Geels, 2002). For example, the Internet was first developed for military use in the 1950s, diffused to academic settings in the 1970s, and found broad commercial use only in the 1990s. By considering the industry, rather than the firm, as the principal unit of analysis we also aim to address a shortcoming of existing adoption literature, which overemphasises individuals and/or organizations as the locus of adoption, ignoring the fact that individual industries can move to adopt particular technologies at different stages in the technology life-cycle. For example, research on IT diffusion has shown that whole industries acted as early adopters, while other industries were laggards due to variations in industry level information processing requirements (Melville and Ramirez, 2008). In a comprehensive review of IT diffusion research, Fichman (1992) argues that although most diffusion research focuses at the individual and organizational level, "*the adoption of IT by other aggregates (small groups, industries) is certainly possible and well-worth of future study*" (pg. 8). Consequently, existing literature supports the need for research to also consider the industry rather than simply the organization or individual as the locus of innovation adoption.

We use RFID technology as an exemplar technology and assess the benefits and costs associated with RFID adoption as the innovation is implemented by an early majority of users (exemplified by healthcare industry), and compare these with existing results assessing the benefits (Curtin et al. 2005; Hellstrom, 2009; Jones et al. 2005; Lee and Ozer, 2007; Sharma and Citurs, 2005) and costs (Hellstrom, 2009; Sharma and Citurs, 2005; Smart et al., 2010) associated with RFID adoption by early adopters (exemplified by the retail and automotive industries).

This paper comprises six sections. Section Two examines previous literature investigating the technology life cycle, and the benefits and costs associated with innovation. The last part of the literature review examines the evolution of RFID and reviews existing studies considering the costs and benefits associated with RFID adoption by early adopters. The research design is discussed in Section Three. The analysis of the interview data on RFID adoption by the early majority of users is discussed in Section Four. Section Five compares the findings from RFID adoption by early majority with the findings in existing literature considering the adoption of RFID by early adopters. Section Six discusses the implications of these findings and concludes the paper.

2. Literature review

The study builds on literature from three main areas: technology innovation lifecycle, the costs and benefits of innovation adoption, and RFID adoption. Each of these literatures is considered in turn in this section.

2.1. Technology innovation lifecycle

One of the most pervasive theories of technology innovation is the diffusion of innovation theory, which proposes that technology adoption follows an S-curve: diffusion rates start slowly, rise and then fall over time, leading to a period of fast adoption squeezed in between an early period of slow take-up and a later period of saturation, until the technology is replaced (Rogers, 1995). Research has refined the diffusion of innovation model by clearly distinguishing three separate stages during technology development and diffusion (Utterback and Abernathy, 1975). For example, the dominant design model (Anderson and Tushman, 1990) argues that technology innovation passes through an era of ferment, followed by the emergence of a dominant design that stabilizes the innovation, and concluding with a stage of incremental innovation when efforts are focused on refining the dominant design. Different types of users, characterised by different attributes, tend to become involved at different stages of technology evolution. Rogers (1995) distinguished between five categories of users: lead users, early adopters, early majority, late majority and laggards. Lead users and early adopters tend to become involved in innovation during the early stages of evolution, when the take-up is generally slow. The majority of users adopt an innovation only once the dominant design has emerged. Late adopters delay even longer, and consider adoption only after a dominant design has become established and an innovation is undergoing only incremental developments. By the time laggards enter, the adoption rates have slowed down and diffusion of the innovation has reached saturation point (Rogers, 1995).

The process of diffusion does not simply involve later adopters imitating earlier adopters; instead it can be seen as a process through which technology evolves and changes to match a wide range of different users needs (Geroski, 2000). Case histories of technology development have noted how technologies change to fit the needs of different users from different sectors as technologies diffuse beyond their original market niches (Geels, 2002). For example, the early development of photovoltaic solar technology was driven by the needs of US and Soviet government space exploration agencies, which required high levels of power generated per unit of cell weight. This need dominated any cost rationale. It was only when the first commercial applications emerged in the 1970s for off-the-grid commercial power use that cost (a key issue for commercial users) become relevant, and technology development started to move away from concentrating solely on power/weight ratios to considering the cost per unit of power generated (The Economist, 2007).

2.2. The benefits and costs associated with innovations

This section reviews the literature on benefits and costs associated with the adoption of innovation.

2.2.1. Benefits

When considering innovation benefits, the implementation literature is often vague in defining precisely which benefits are being considered, often considering them only in terms of superior organizational performance (Klein and Sorra, 2002; Meyer et al., 1999). One reason for this approach is that the focus of implementation studies tends to be on identifying "success factors" associated with effective implementation rather than on identifying what "success" represents (Klein and Sorra, 1996; Linton, 2002; Meyer et al., 1999; Repenning, 2002). Positive outcomes from implementation are said to include time- and cost-efficiencies and effectiveness, full utilisation of innovation capacity and capability, increased productivity and reduction of process errors (Meyer et al., 1999), and improvements in profitability, customer service and employee morale (Klein and Sorra, 1996). These benefits often tend to be measured as a generic variable such as "innovation effectiveness" (Klein and Sorra, 21996). Drawing from O'Connor et al. (1990), Linton (2002) classifies the benefits from innovation implementation into four categories: (1) implementation, integration and institutionalisation; these refer, for example, to the extent of innovation use or whether the innovation is employed to meet its original objectives; (2) human partnership dynamics, which include the well-being and satisfaction of the workforce; (3) operational effectiveness, including customer responsiveness and work performance variables; and (4) economic performance, such as return on investment (ROI) and cost reductions.

Drawing from innovation adoption studies, a recent review of the literature has identified two approaches to categorise benefits associated with process innovation (Bunduchi and Smart, 2010). The first approach considers benefits depending on their strategic importance and differentiate between three categories : (1) direct benefits from the improved transmission of information and the resultant cost savings from reduced document handling; (2) indirect benefits from improved efficiency within the firm, and improved relationships with suppliers and customers (Chwelos et al. 2001; Iacovou et al. 1995); and (3) strategic benefits relating to the ability to forge closer business links with customers and/or suppliers (Jimenez-Martinez and Polo-Redondo 2004 ; Weber and Kantamneni 2002). The second approach to classifying benefits considers the link between benefits and the focal firm adopting the innovation. This approach identifies two categories of benefits: (1) first order benefits are related to the firm's action and include (a) operational benefits such as lower transaction and production costs, and (b) strategic benefits that result from changes in the buyer-supplier trading relationship; and (2) second order benefits incorporate the influence of factors beyond the control of the focal firm and relate to the outcomes that the innovation has had on the success of the focal firm relative to its competitors (Cunningham and Tynan, 1993; Mukhopadhyay and Kerke, 2002; Subramani, 2004). We focus here on first order benefits.

Both typologies used in the adoption literature differentiate between operational benefits, in the form of either direct or indirect benefits, and strategic benefits. Operational benefits are related to cost reductions and improved efficiency in organization's operations. Strategic benefits relate to changes in the relationship between the supply chain members involved in the innovation (see Table 1). To some extent, this classification between operational and strategic benefits incorporates the categories of benefits identified in the implementation literature. Economic performance relates to cost reductions, and is included within the direct benefits category, while operational effectiveness and human partnership dynamics are incorporated within the indirect benefits category. The implementation, integration and institutionalisation category includes variables such as the fidelity of and degree of implementation, the extent of utilisation and the workflow integration (O'Connor et al, 1990) and refers to variables that assess the ways in which the innovation has been implemented within an organization, rather than innovation outcomes in terms of changes within the organization.

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2.2.2. Costs

While the benefits associated with organizational innovation have been widely examined in both the adoption and implementation literature, costs have received much less attention. Even when they are considered, innovation costs are generally acknowledged as a single, high level variable such as the "financial costs of developing and implementing" an electronic interchange system (Chwelos et al, 2001) in the adoption literature, or simply "the costs of implementation" (Linton, 2002) in the implementation literature. Few studies have attempted to explicitly differentiate between categories of costs associated with innovation adoption (Hollenstein and Woerter, 2008; Premkumar et al., 1994; Zhu et al., 2006). Drawing from existing studies of inter-organizational process innovation, recent work has developed a systematic framework for examining innovation costs (Bunduchi and Smart, 2010). The framework identifies six categories of costs associated with process innovation (see Table 2).

Development costs are incurred by organizations involved in the development of a process innovation (usually a form of IT) and result from participation in the elaboration of the technology. The development effort involves both the in-house development of a new process technology, and/or the effort involved in collaborative development (Tidd et al., 2005), including membership fees for participation in standard development consortia (Gupta et al., 2008). Utterback (1974) estimates that this early stage cost of originating and developing a successful innovation is about 15-30% of the total cost of bringing the innovation into use.

Initiation costs are borne by organizations that acquire a technology from external developers, and include the costs associated with building awareness of the innovation. With few exceptions (see Damanpour and Wischnevsky, 2006; Meyer and Goes, 1988), exiting literature generally ignores the effort involved in searching for and acquiring innovations. However, research has found that most of the ideas for innovations come from outside the firm, and a significant number of innovations (33%) are wholly adopted from other firms (Utterback, 1974). Consequently, searching for technical possibilities to meet existing needs (Utterback, 1974), building awareness and learning about the potential of particular innovations are important activities (Meyer and Goes, 1988) that require time and effort and, therefore, must incur some costs (Bunduchi and Smart, 2010).

Switching costs are the costs arising from the need for compatibility between existing organizational and technological assets (Powell and Dent-Micallef, 1997) and a new technology (Farrell and Shapiro, 1988; Klemperer, 1995). Switching costs have been identified as one of the key barriers to the adoption of innovations by researchers examining innovation from both economics (Farrell and Saloner, 1985; Tang and Zannetos, 1992) and information system (Forman, 2005; Zhu et al., 2006) perspectives.

The cost of capital results from the uncertainty of any investment in innovation. Two types of uncertainty associated with investments in innovations have been identified (Mata et al., 1995): (1) technological uncertainty, which reflects the risk that the investment will not meet its performance, time and cost targets. Hollenstein and Woerter (2008) distinguish between costs associated with technological (i.e. technical performance) and economic (i.e. time and cost) uncertainties; (2) Market uncertainty reflects the risks of negative reactions from supply chain partners and the general public (Mata et al., 1995; Markus 2000).

Implementation costs are associated with acquiring and implementing an innovation, and include direct and indirect costs (Irani et al., 1997). Direct costs are readily attributable to the acquisition and operation of technologies, notably equipment costs (Irani et al., 1997), while indirect costs include organizational- and human-related costs (Irani et al., 1997; Ryan and Harrison, 2000). Human costs can be attributed to individuals and result from on the job training (Ryan and Harrison, 2000), management time (Irani et al, 1997) and resistance to the new technology (Hollenstein and Woerter, 2008). Organizational costs arise due to changes in the existing practice to support the integration and assimilation of the new technology (Hollenstein and Woerter, 2008; Irani et al, 1997).

Relational costs are associated with the relational context in which the innovation is implemented. The relational context is important because the adoption of any process innovation that spans organizational boundaries requires the consideration of costs (and benefits) to be extended across all the partners involved in adoption (Johnstone and Vitale, 1988). Trust is one of the key relational variables that has been studied in the context of inter-organizational innovation adoption (see for example Hart and Saunders, 1998; Kumar and van Dissel, 1996). Lack of trust among innovation partners has been shown to breed conflicts and tensions among potential adopters (Allen et al., 2000), increasing the costs associated with innovation adoption.

Research on particular types of process innovation, such as RFID technologies (Smart et al., 2010), and electronic patient records in health services (Carney, 2001), has identified ethical costs as another significant category of process innovation. In the context of electronic commerce, Hollenstein and Woerter (2008) also identified security costs – the costs caused by problems of data protection, and analogous to ethical costs – as important in shaping the adoption of a new technology. Ethical costs are associated with potential breaches of privacy and health concerns (Smart et al., 2010).

The costs identified in the literature are illustrated in Table 2.

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Mukhopadhyay et al. (1996) have suggested that innovation outcomes vary depending on the stage of the technology life cycle at which data was gathered, and found evidence of such variability for the direct benefits associated with the adoption of electronic data interchange. Similarly, Bunduchi and Smart (2010) have suggested that the costs associated with process innovation might vary with the stage reached in the innovation life cycle. The aim of this paper is to explore whether the benefits and costs associated with technology adoption do indeed change as the technology at different stages in its life cycle diffuses across sectors. We focus here on the adoption of RFID technology, and examine whether the magnitude of the benefits and costs associated with RFID adoption has changed during the technology life cycle.

2.3. RFID technology

Our focus on RFID technology is primarily a consequence of the opportunities it offers to carry out contemporaneous studies as innovation happens. In doing so, we follow Linton's (2002) recommendation for innovation implementation researchers to avoid retrospective studies. Since 2000, RFID technology has emerged as one of the most significant process innovations in supply chain contexts. RFID promises to increase visibility in supply chains (Angeles, 2005), to reduce labour and inventory costs and to improve supply chain coordination and product availability (Lee and Ozer, 2007). High costs remain, however, a significant obstacle to the wide spread adoption of RFID both within the early adopting industries (Schmitt & Michahelles, 2009) and to other sectors, such as the hospitality industry (Oztaysi et al, 2009).

2. 3.1. The evolution of RFID technology

RFID is a means of identifying unique items using radio waves. The technology was developed during WW2 to allow for the identification of friendly aircrafts. Although RFID technology is more than 50 years old, it was first used in business applications only during the 1980s; initial applications included electronic road toll collection, railcars tracking and animal tracking (Dew, 2006; Dew and Read, 2007; Jones et al., 2005). Adoption of RFID by lead users in sectors such as farming and public transport stimulated the growth of the RFID market in the 1980s, reducing the cost of RFID tags and enabling the diffusion of RFID applications to other sectors, including keyless entry systems for buildings and cars, and reusable metro and bus passes (Dew, 2006). However, RFID supply chain applications became popular only following the mandates from large organizations like Wal-Mart and the U.S. Department of Defence in 2003. These mandates attempted to force suppliers to adopt RFID for tracking and tracing goods in supply chains by 2005 (Prater and Frazier, 2005; Wu et al., 2006). Although the mandates were not entirely successful, they were key in positioning RFID as a critical technology in retailing and for the manufacturers of fast moving consumer goods, and stimulating investment in RFID development and pilot applications beyond the initial lead user sectors (Brown and Russell, 2007).

In tracing the diffusion of RFID, Chao et al. (2007) identify the automotive and transportation sectors as early adopters of RFID technology: the automotive industry began to experiment with RFID technologies in applications such as vehicle immobilizers in the early 1990s (Schmitt et al., 2007). However, it was retailing and related manufacturing industries that played a significant role in driving the wide spread adoption of RFID technology through mandates, and its further development for business applications through the founding of RFID development and standardization organizations such as

AUTO-ID and EPCGlobal in the late 1990s (Dew, 2006; Gerst and Bunduchi, 2005a). During this period the lack of a unified RFID standard and the high costs of tags were big hurdles in the widespread adoption of RFID (Wu et al., 2006). To overcome these hurdles, standardization efforts intensified during the early part of the 2000s, and ISO and EPCglobal emerged as the two most influential bodies in the development of RFID technologies (Dew, 2006; Gerst and Bunduchi, 2005a). During the early part of 2000s, the retail and related manufacturing sectors were the most widely reported adopters of RFID. For example a recent literature review of RFID studies (Schmitt and Michahelles, 2009) identified 14 published studies of RFID that specified the sector of adoption (from a total of 31 reviewed studies), and eight of these fourteen studies focussed on retail. While other manufacturing sectors, such as the automotive industry, have also been early adopters of RFID, diffusion of RFID in the retail sector was much more extensive, primarily due to the lack of a commonly agreed standard within the automotive industry (Schmitt et al., 2008).

During the early 2000s, incremental improvements in technology, coupled with economies of scale in production as adoption rates in retail increased, led to gradual reductions in the cost of RFID tags (Jones et al., 2005). The ratification of the EPC standard by ISO in 2006 also reduced fears that RFID development would be based on competing, incompatible standards. While a best-practice application is still lacking in many areas, as a result of the developments during the 2000s the number of pilot implementations taking place other than in lead users and early adopter industries increased significantly (Banks et al. 2007). In healthcare, for example, the use of RFID intensified after the mid-2000s (Chao et al., 2007; Wang et al., 2006). While adoption of RFID beyond early adopters is not limited to the healthcare industry, healthcare is generally considered as RFID's next major adopter (Tzeng et al., 2008; Wang et al., 2005).

RFID applications in hospital settings can generally be considered under two broad headings: (1) the tracking and identification of medical and operating equipment; and (2) the tagging of personnel and patients (Nagy et al., 2006). These applications are seen as reducing the time and costs of locating hospital equipment and personnel. However, the widespread adoption of RFID in healthcare beyond pilot implementation has faced many obstacles, particularly the identification of the real benefits and costs in terms of patient safety, the difficulties in identifying a real ROI (Kuo and Chen, 2008), and dealing with ethical implications. The second form of hospital RFID application in particular, has significant ethical implications with potential for questions about the invasion of privacy. There is a risk that patients and personnel may feel insecure because they are not clear when and where the RFID scanners may be used for tracking or identification, and who would have access to this data (Katz and Rice, 2008).

In mapping the diffusion of RFID technologies we can therefore identify farming and public transport industry as the lead users during the late 1980s and early 1990s, when the focus was on technology development. Retailers and manufacturing industries can be considered as early adopters during the 1990s and early 2000s, when the focus shifted towards technology standardisation to support adoption on a global scale (Gerst and Bunduchi, 2005a). As the technology has become more widespread, and standardization efforts intensified during the mid-2000s, the pace of adoption has accelerated and the focus has moved to developing a wider range of business applications in a variety of industry settings.

Since the mid-2000s there is evidence of a move to the early majority of users adopting RFID, with the healthcare sector being a prominent user within this group.

2.3.2. The benefits and costs associated with RFID adoption – lead users and early adopters

Studies on RFID in interorganizational settings have identified a range of direct benefits associated with RFID adoption by early adopters, particularly where RFID has been envisaged as a replacement for barcodes. Because RFID eliminates the need for line-of-sight, data can be readily updated at the level of individual items. In addition, the use of radio signals makes it possible both to read multiple tags without any human agency, and to specify which tags are read (Garfinkel and Holtzman, 2005). This dual ability can lead to reduced labour and inventory handling costs (Curtin et al. 2005; Jones et al. 2005; Lee and Ozer, 2007). In addition to these direct benefits, Lee and Ozer (2007) suggest that RFID adoption can offer indirect benefits. These indirect benefits result from the ability of RFID applications to (i) make it easier to find misplaced items; (ii) reduce shrinkage from theft; and (iii) reduce transaction errors. Together these indirect benefits can result in improved efficiency as a consequence of employees spending less time and effort identifying and resolving problems brought about by missing inventory (Lee and Ozer, 2007). Sharma and Citurs (2005) also suggest that RFID will lead to improved inventory management, reduced stock-outs, decreased theft and fewer scanning errors as key benefits for retailers and manufacturers. Sharma and Citurs (2005) term these benefits "direct benefits" associated with operational savings resulting from increased internal efficiency of the organization. In our typology, however, they are considered to be "indirect benefits" associated with improved efficiency. Direct benefits are limited to cost savings (such as labour and inventory) that can be readily attributed to the introduction of RFID. In addition to indirect benefits linked to in the increased efficiency of firm's internal operations, Sharma and Citurs (2005) argue that RFID adoption can also lead to indirect benefits such as higher customer satisfaction from fewer stock-outs and faster service, and improved insight about customer's requirement.

Generally, existing studies on early adopters have emphasised direct and, to some extent, indirect benefits associated with RFID adoption. Bottani and Rizzi (2008) for example found that the direct benefits associated with savings in inventory and labour are the most important benefits for both distributors and retailers. A review of studies on RFID adoption in retail between 2002 and 2006 found operational efficiency, improved visibility (indirect) and reduced costs (direct) as the three most significant benefits (Bhattacharya et al., 2007). In contrast, strategic benefits are very rarely mentioned. For example, an in-depth case study of two RFID pilot trials in retail organizations found no mention of strategic benefits in the cost-benefit calculations. Indirect operational benefits were also largely omitted: the focus was primarily on direct benefits (Hellstrom, 2009).

When considering costs, existing studies have emphasized direct implementation costs, in particular the cost of tags, as the most significant RFID cost for adopters (Banks et al., 2007; Jones et al., 2005; Prater and Frazier, 2005; Wu et al., 2006). Similarly, a study examining the costs associated with the adoption of RFID in the automotive industry found that, with the exception of the costs of tags, direct implementation costs were not significant for early adopters (Smart et al., 2010). Other direct implementation costs mentioned occasionally in studies on early adopters include hardware and software installation costs, training costs

(Hellstrom, 2009), reader equipment costs (Bottani and Rizzi, 2008; Hellstrom, 2009), and maintenance costs (Schmitt and Michahelles, 2009). Indirect implementation costs, such as the time that employees spent on learning and using the system are generally ignored (Hellstrom, 2009). The only form of indirect implementation cost mentioned in studies on early adopters is the integration costs of RFID software with existing systems (Hellstorm, 2009).

In addition to the cost of tags, other categories of costs that are found significant for early adopters in the automotive industry (see Smart et al., 2010) include development costs, ethical costs and the cost of capital (see Table 5). Similarly, Koh et al. (2006) found that the risk associated with the uncertainty of RFID technology, one of the key components of the costs of capital, was the most significant risk for the adoption of RFID in the retail industry. Ethical costs, in particular the costs associated with consumer privacy, were also found to be significant for early adopters in both the automotive industry (Smart et al., 2010) and in the retail sector, where privacy concerns were identified as the most important challenge to adoption (Bhattacharya et al., 2007; Kelly and Erickson, 2005).

The evidence for the presence of relational costs is also very weak for early adopters (Smart et al., 2010). It was suggested that the majority of early adopters' RFID projects were taking place within single organizations or were pilot studies, and that buyer-suppliers relationships were consequently not affected by limited implementation (Smart et al., 2010).

Smart et al. (2010) suggest that further research is needed to investigate the magnitude of the different categories of costs as the technology moves beyond lead users and early adopters. This paper goes some way towards addressing that suggestion.

3. Research methodology

Research looking at technology development and/or adoption and diffusion tends to focus on case study histories of technology development (e.g. van den Ende and Kemp, 1999; Geels, 2002) and diffusion (e.g. Attewell, 1992), or to use quantitative surveys to identify the factors shaping technology adoption at a single point in time (e.g. Chwelos et al., 2001; Cooper and Zmud, 1990; Premkumar et al., 1994). The first method allows researchers to explore in-depth the processes surrounding the development of a particular innovation, while the second method supports the generalisation of findings across different organizations and/or sectors. However, these approaches are largely retrospective in nature. The most significant limitation of retrospective research is the difficulty of determining cause and effect from reconstructed events (Leonard-Barton, 1990). Moreover, with retrospective studies respondents may not recognise an event as important when it occurred, and thus may not recall it afterwards (Leonard-Barton, 1990). Similarly, historical case studies tend to emphasise "accepted" accounts of the historical significance of socio-technical development, without a critical evaluation of the sources of data (Genus and Coles, 2008).

In order to address some of these criticisms, this study used a contemporaneous qualitative case study research design. We focussed on the adoption of RFID by an early majority sector, healthcare. We compared the outcomes in the healthcare sector - an early majority adopter in Rogers (1995) classification - with the results from the literature review outlined in Section 2.3 of the adoption of RFID by early adopters (Rogers, 1995). There are three reasons for adopting this approach to the research. First, we wish to explore the dynamics of the outcomes that a technology has on its adopters: there is currently too little understanding in this area to be able to construct informed hypotheses. While existing studies have largely addressed the adoption and diffusion of technology and the impacts that innovations have at one point in time on adopters, there is little theoretical development on the magnitude of these impacts over time. When there is a lack of well defined theoretical frameworks, an exploratory, qualitative study (rather than a large scale survey) is more appropriate to support theory development (Yin, 1994). Second, this research conceptualizes technology as a social construct (Russell and Williams, 2002) shaped by the organizational context in which it is used (Ngwenyama and Lee, 1997). Case study research (rather than a survey) enables researchers to capture and understand the social and organizational context in which the phenomenon – in this case, the use of RFID - occurs (Yin, 1994). Third, as Creswell (1994) notes, a phenomenon under development, such as RFID, requires a flexible and exploratory research design in order to capture the changes that can occur during the lifetime of the research project. Moreover, we aim to gather the perceptions of innovation impacts as they happen, rather than relying on retrospective data. In doing so, we benefit from a close proximity in time to current events which, as Leonard-Barton (1990) suggests, increases the likelihood that researchers can determine the sequence and nature of events more accurately. In our case, it is important to understand whether different categories of benefits really happened when the technology was adopted, or whether they were constructed later, after the technology had been in use for a period of time. A qualitative research design allows both the flexibility and exploration that are required for our contemporaneous study of RFID (Creswell, 1994).

The work focused on the perceptions of technology supplier organizations, who generate and coordinate technology development. The sample included innovation generators (technology development firms), and coordinators of technology development and adoption (technology standardization organizations, and public policy research and development (R&D) organizations). In the early stages of technology development it is common for a range of organizations beyond users (including technology supplier organizations) to play a significant role in shaping the generation, acceptance and implementation of technology innovation (see Jakobs, 2009). Technology supplier organizations have significant experience in generating and implementing technologies in a range of user contexts and are able to transfer knowledge between these contexts. For example, in the case of RFID, existing studies have shown the importance that standardisation bodies and technology consultancies played in creating a body of common knowledge on RFID adoption (Dew and Read, 2007).

Two units of analysis can be distinguished in this study. The main unit of analysis is the industry in which the innovation is adopted. Within the industry, the second unit of analysis (what Yin (1994) refers to as the embedded unit of analysis) is the adopting organization. The industry is seen as the aggregate adopter (for example early adopter or laggard), though it is individual organizations that experience the benefits and costs associated with the technology adoption. A focus on industry, rather than individual organizations, is justified by the nature of RFID diffusion which, as discussed in section 2.3.1., has moved gradually from one sector to another. This gradual diffusion across industry sectors is typical of many radical new innovations, such as the Internet or photovoltaic technology. By drawing from industry-level data (technology supplier organizations) rather than at an organizational level (adopting organizations within the industry) we aimed to gather data that was generic at the level of the industry, rather than specific to individual organizations.

We recognise that there are two limitations associated with this approach. First, we do not account for cross-sectoral differences in benefits and costs. For example a literature survey of RFID adoption in the retail and manufacturing sectors found that while the benefits in both sectors were similar, it was possible for the relative importance of these benefits to vary between sectors (Bhattacharya et al., 2008). However, the results of this study should be treated with some caution. There were many more studies in retail than in manufacturing and the extent of adoption was greater in retail: both of these factors may influence the results, rather than there being any significant differences between the two sectors. Second, we use only healthcare as an example of an early majority adopter. We are not arguing that healthcare is representative of all early majority adopters. Rather, in selecting healthcare, we used Miles and Huberman's (1994) intensity criterion. Existing research widely depicts RFID as the next "wave of innovative technology" in healthcare (Tzeng et al., 2008), and reports suggest that this sector will be one of the most intensive early majority adopters of RFID (Collins, 2005; Tzeng et al., 2008; Wang et al., 2006). Cases where the phenomenon is the most intensive provide the advantage of offering rich data for analysis (Miles and Huberman, 1994).

Data was gathered from primary and secondary sources. Primary data was collected through five in-depth semi-structured interviews with representatives of technology suppliers involved in RFID adoption in healthcare settings. Interviews were carried out by telephone to overcome problems with access to interviewees, who were spread around Europe and the US. The details of the interviewees are summarized in Table 3. Interviews were carried out using an interview guide (Patton, 1987), focusing on interviewees experiences of RFID implementation and development, but leaving the interviewer to develop further questions as specific issues emerged.

The interview guide included two major topics: benefits and costs, and asked the respondents to discuss the realised benefits, costs, challenges and risks that hospitals have experienced as a result of RFID implementation. The interview asked about the specific experiences of the respondent. For example, the standards body representatives were asked to discuss the benefits and costs associated with the standardisation of RFID for hospital applications, as well as the impact of standardisation on hospitals' involvement with RFID. The consultants' interviews were focused more on eliciting their perceptions of benefits and costs, based on their experiences of running pilot implementations with specific customers.

Interviewees were identified using opportunistic sampling (Miles and Huberman, 1994), using respondents who were selected for their ability to act as key informants (Patton, 1987). Respondent validation was used to check the accuracy of the data obtained during the interviews (Payne, 1999). Interviews were recorded and subsequently transcribed. One interview was conducted in German: this was first transcribed and then translated into English by a fluent speaker of both languages.

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The sources for secondary data comprised publicly available documentation about RFID development, articles from practitioner magazines and newspapers, and websites of organizations involved in RFID development and implementation in healthcare. We relied, for example, on online sources such as The RFID Journal and websites of organizations such as AUTO-ID and EPC Global, which provided rich data for tracing the development and diffusion of the technology, and contained case studies of RFID applications in a range of sectors. We also used technology consultancy whitepapers and reports, which were useful in tracing the types of applications and potential benefits of the technology. We have used secondary data for two purposes: first, as recommended by Remenyi et al. (2000), secondary data enabled us to set out the context for the interviews, and second it helped us to triangulate the interview data.

Coding followed a deductive approach. Before fieldwork was carried out a list of codes was developed, based on the literature review (Miles and Huberman, 1994). The initial list included two broad categories of codes: (1) those relating to RFID benefits including direct, indirect and strategic benefits; and (2) those associated with RFID costs such as development, initiation and switching costs, cost of capital, direct and indirect implementation costs, and relational and ethical costs. Each transcript was coded by the first author to identify instances of the benefits and costs detailed in the coding list and also to check whether additional costs and benefits emerged that had not previously been identified in the provisional list. The coding was then checked by another author. Further analysis of the case materials was based on making detailed descriptions of the materials and of the case setting (Stake, 1995). The case narrative was built following a process of making comparisons, noting relationships between codes, and identifying patterns and themes (Miles and Huberman, 1994).

4. RFID adoption in healthcare: Results

This section discusses the respondents' perceptions of the benefits and costs of adopting RFID technology in the healthcare sector.

4.1. Benefits

The interviewees suggested that the main use of RFID in hospital settings is for the auto-identification and tracking of objects and/or people. This functionality enables hospitals to deploy a range of RFID applications in two major areas: (1) inventory management; and (2) to support internal processes such as asset tagging in operating theatres and patient flows. Each of these applications has different benefits, and the respondents emphasized the need to consider each application independently when trying to understand the benefits arising from implementation: "*How RFID should be implemented … depends mainly on the nature of the application and on the understanding we have of that specific application.*" (RDP). Some of the most common RFID hospital applications are summarized in Table 4 and their benefits are discussed in detail in the rest of this section.

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According to our respondents, to date the most widely used RFID application for inventory management in a hospital environment is asset tracking. Asset tracking leads to significant inventory cost reduction in two different ways. First, asset tracking reduces the incidence of lost items: "*[with RFID] you have a good … chance that you will know at least where something was last if it has been read, if it has passed through a certain point*" (SBUK). Accurate tracing and tracking of assets using RFID allows hospitals to carry lower stock: "*the problem there is that some nurses hoard items in order to support surgeons. It is not unusual to find stents hidden up in the ceiling tiles or in people's desks … By moving to RFID enabled cabinets a typical hospital can save $300,000 to $500,000 in inventory that's hidden away somewhere.*" (SBUS). In addition, automatic asset tracking reduces the need for manual tracking, improving the efficiency of inventory management by allowing staff to spend their time on more productive activities: "*Every department needs not less than ten clean infusion pumps. It is done today manually. … you have these guys checking through the floors, checking the status in each room, then replenishing the rooms … We [can, in the future] count [these] automatically through RFID*" (TVUS).

In addition to the savings available from improved inventory management, RFID can also be used to monitor equipment, ensuring a reliable audit trail and enabling tracking of equipment requiring maintenance, and assisting in checking the condition of equipment. This is particularly important where regulations aimed at maximizing patient safety require a strong preventative maintenance regime. As one vendor explained: "*Equipment maintenance is steered mainly towards clinical engineers, and biomedical treatment. These guys are in charge of the maintenance of the asset. The problem is that there are a lot of regulatory issues. You have to do preventative maintenance on time: there are audits around this. But when they need to do preventive maintenance they maybe can't find a specific device … Now [with RFID] we are optimizing the process and automatically finding where those assets are. If I need to do a recall for 200 devices … and I can only find 190, there are 10 wandering around the hospital, maybe being used by a patient, then there is patient safety issue. So the drivers here are patient safety. And the driver here are actually the regulatory compliance - being able to maintain the devices on time*" (TVUS).

RFID can also be used to assist in monitoring the condition of assets. Condition monitoring applications enable hospitals to monitor the temperature, humidity and motion of medical assets and are also driven by the need to ensure patient safety. In addition, the use of RFID to assist in condition monitoring increases efficiency, because it can replace manual monitoring and reduce waste. As one respondent explained: "*by placing [the sensors] in a refrigerator, instead of the nurse going through hundreds of refrigerators twice a day and manually logging temperatures, it is done automatically … So the driver here again is also in some cases patient safety. You want to reduce spoilage for example, for items that are stored in the refrigerators … and in addition again, regulatory compliance is a driver*" (TVUS).

Another application relating to the safety of patients, and also in this case of staff, is the ability to locate patients and staff in the hospital, As one vendor explained: *"[the ability to track staff and patients] is mainly geared towards at risk patients, like Alzheimer's, dementia [and] wandering trauma patients. In those cases you want to do several things. First, if there is an emergency outside the room or not at the bedside, you want there to be some kind of mechanism, a wireless call button and a tag, that can alert others. Apart from saying 'Hey I have a panic situation', you know the location where that incident occurred. And the other two things you want to do are, if a [vulnerable patient] leaves the ward or the building unattended, you want to know that immediately. Or if they are entering restricted areas, if they are entering a room that has drugs and medication, you want to know about that. With regard to staff, when dealing with mental wards or patients that can pose a risk for the staff, then the staff can have these tags also and they can click on a call button in a stress situation"* (TVUS).

Finally, RFID could be potentially deployed to optimize departmental operations by coupling it with workflow and resource management applications. As one of the standardization body representatives explained: "*hospitals are also looking at their internal processes and how RFID can be used to improve them, so they've been looking at a number of different areas. One of them is the operating theatre, with the thought of how to make it safer, more efficient and be able to increase the operating theatre turnover*" (SBUS). Such applications are not yet widely used, but respondents emphasized that they enable hospitals to reduce costs through improved utilization of existing resources and equipment, while also speeding up the patient throughput and reducing waiting times.

The benefits of RFID adoption associated with process change build upon the success of RFID asset tracking applications: "*an automated way of capturing a code … [gives you] the necessary ingredients to reduce …a £900 million loss because there is a … very good chance that you will know at least where something last was if it's been read … You possibly then start talking about aligning that item with the person that pushed it past that read point, but then you start talking about process, so always the potential is there to drive more efficiency and effectiveness into the NHS and improve patient care …*" (SBUK). This suggests a progression in RFID applications in healthcare environments, moving from applications that enable costs reductions to applications that lead to more profound changes in existing processes to bring about greater efficiencies and improved quality of care. Our data suggest that, for healthcare RFID applications, it is the potential to obtain these longer-term, indirect benefits, that needs to be emphasized in the calculation of ROI, especially in comparison with alternative technologies: "*the bar code would be less expensive initially. In other words, the ink for barcodes is a lot less expensive than RFID tags, but one of the things that we've noticed is that people will start looking at the overall cost, or the cost of ownership. So although a barcode is seemingly cheaper, when you consider other things like infection control, for example, you want a nurse or other helpers to touch fewer things … This suggests a good RFID implementation.*" (SBUS).

These indirect benefits, associated with increased efficiency as a result of business process change, are currently more significant drivers of RFID adoption in a hospital environment than the direct benefits associated with inventory cost reductions. As one of the technology vendors explained, "*RFID is a tool to enable clinical staff and hospitals to realize some kind of automated control of workflow; this will help and should help to increase the quality of* *healthcare and to decrease costs of the workflow. That's the most important goals to think about in RFID implementation*." (TVG).

4.2. Costs

Analysis of the interview data resulted in the identification of seven categories of cost categories: (i) development costs; (ii) initiation costs; (iii) switching costs; (iv) the cost of capital; (v) direct implementation costs; (vi) indirect implementation costs; and (vii) ethical costs. Each of these costs is examined in turn.

4.2.1. Development costs

Technology developers have been actively involved in R&D work in order to test RFID technology in real operating environments. The R&D has enabled the vendors to identify possible benefits and common implementation patterns: "*We have something like … a small test clinic. It is equipped with RFID technology, so we are continuously doing tests on this technology, in combination with medical devices and/or in combination with IT systems. The test clinic has been in use for 3 years now and progresses continuously … the main aim is to find out … the maximum profit for this technology*" (TVG). However, the development costs are not only supported by technology vendors; pilot applications within the actual adoption context are critical in assessing the actual outcomes and implications of implementation of RFID within hospital settings: "*it is impossible to do such pilot projects only in a laboratory. You will never ever get real results; you need real hospitals to do such pilot projects! … You have to enter the real world, the real hospital, to do pilots*" (TVG). It is this collaboration between technology vendors and the hospitals that participate in pilot implementations that enables early RFID applications to be developed. However, participating in pilot RFID applications involves significant setup costs for hospitals: "*it's hard to convince [hospitals] to start a pilot project … [Even] if you start such a pilot project free of charge, [hospitals] won't come out and say: 'Oh yes, let's do it!' because they know there is a lot of additional work starting from the implementation, from the installation until the system is running*" (TVG). Consequently, development efforts, including the costs associated with the development of RFID applications, are jointly supported by RFID technology vendors and adopters.

4.2.2. Initiation costs

Hospitals participating in pilot RFID implementations also incur initiation costs associated with acquiring the knowledge to make a decision on whether to adopt RFID. Respondents described high initiation costs as a significant deterrent to RFID adoption. They emphasized the lack of information about the benefits and costs associated with RFID applications, which makes it difficult for potential adopters to obtain the data required to assess the ROI: "*[there is] very limited data available. Unfortunately, it has been difficult to get cost-benefit data from [hospitals] … yet it is essential to get clear data and establish and communicate ROIs for RFID applications in healthcare*" (RDE). Using pilot studies to obtain accurate information about the ROI is seen as crucial to supporting the decision-making process that will ultimately lead to the diffusion of RFID in healthcare. In the absence of this information, users have no easy way of assessing potential RFID applications. This increases initiation costs, and deters adoption.

The difficulty of assessing the true potential of RFID was linked by respondents to the fact that the technology is still in the early stages of development: *"I think that no one knows* *about the real benefits and real ROI to start a pilot project. We are in a very early phase of adoption and therefore it is not yet possible to say 'it is sufficient return' to the medical department or to the IT department … we are in the phase of pilot projects and we're not yet in the phase of real, everyday-life applications"* (TVG). Consequently, RFID adoption is patchy, and lacks "good practice" standardized applications. RFID applications tend to be segmented for specific tasks; for example it is used for patient identifications or for tracking for hospital beds. Currently, there is no integrated solution that links the different potential healthcare applications. According to the interviewees, such integrated solutions are critical to enable potential adopters to gather accurate information about the overall real benefits and costs of RFID in hospital settings: "*There is no real insight into the best benefits. And [the benefits are] not yet available because at the moment we don't have integrated solutions … for the complete hospital workflow or for the complete hospital"* (TVG).

4.2.3. Switching costs

Switching costs arise from the lack of compatibility between new RFID applications and existing hospital systems and/or technologies. In hospital settings, one of the most significant sources of incompatibilities between existing systems and RFID is the potential for radio interference with existing medical equipment. Most older equipment is not properly protected against devices operating in high-frequency ranges: "*medical equipment … [that] was built or purchased ten to twenty or so years ago may not have been shielded enough to protect it from RF. If you have an RF reader that is right next to it, it will provide some interference"* (SBUS). This creates switching costs for hospitals that rely on old technology. A second, more widespread, source of switching costs arises from the need to integrate RFID applications with existing hospitals equipment: this integration activity tends to be characterized by a piecemeal approach to IT adoption: "*hospitals have a lot of equipment and they typically tend to purchase the technology in bits and pieces. That could cause a problem when you try to integrate it all: one of the things about RF as you see it [becoming] more pervasive in different [hospital application] areas … [is that hospitals] really need to start thinking about the overall [systems] architecture, and how this blends together*" (SBUS). Because RFID adoption is currently concentrated in discrete pockets, and pilot applications are limited to particular departments, switching costs are still low.

Unlike in earlier work (Smart et al., 2010) no evidence was found in this study to suggest that vendors were concerned about compatibility between current and future RFID applications in hospitals. In this case, established technical standards for RFID interfaces have been developed, eliminating the switching costs associate with any future (in)compatibility: "*the interfaces are standardized … so with each [RFID] product you use standards plugs at either end of a product*" (SBUK)

4.2.4. Costs of capital

The majority of the cost of capital is associated with technology uncertainty, in particular, technical and financial risk. Respondents perceived RFID as still not a fully mature technology, and felt it might not deliver the necessary performance and/or the expected ROI. The lack of maturity of RFID was discussed primarily in terms of the existence of technical standards and the lack of business application standards.

The respondents emphasized the benefits that existing technical standards provide for the adoption of RFID in healthcare: *"I think standards are important because standards enable* *the entire hospital community not to have these [idiosyncratic] solutions. [This is important.] specifically for an industry like the healthcare industry where it's important to be able to share a lot of the knowledge and experiences in order to [...] increase the overall quality of care"* (SBUK). The presence of common technical standards reduces the incompatibility risk associated with the adoption of RFID innovation, making it possible to interlink different RFID applications and therefore eliminate any future technical compatibility problems. Common standards therefore reduce the technical risk of the investment. Respondents agreed that for healthcare applications, there is no need for further technological standardization: *"I don't think there is a significant need for additional standard; especially for healthcare, because we can use the technologies already developed for the applications"* (TVG).

While the technical standardization in the RFID area was viewed as adequate, most respondents emphasized the lack of a standardized RFID business application: "*there isn't a typical implementation [of RFID in the hospital setting]"* (SBUK). As was noted for initiation costs, the lack of a global, common "good practice" RFID application increased the uncertainty surrounding the real benefits and costs associated with RFID adoption. This uncertainty heightened the financial risk associated with the investment in RFID. The lack of a standard application also created difficulties in assessing whether the RFID investment would deliver the expected performance improvements. This uncertainty about the ROI and the technical performance associated with RFID applications in hospital settings resulted in high costs of capital. When asked about the main source of the uncertainty surrounding RFID adoption, one respondent answered: "*first of all it's the ROI. Even for a pilot you have to invest. You never know what the return of this investment will be. The other problem is* *performance, [whether] the hospital solutions … [will] work according to the requirements or the expectations you have beforehand.*" (TVG). Consequently, while the standardization efforts have progressed to address the technical requirements of the technology, from a business application perspective, RFID still lacks a standard application for the particular user context: this creates uncertainties and increases the cost of capital.

4.2.5. Direct implementation costs

In considering the implementation costs, respondents mentioned the high costs of RFID tags, especially in comparison to the traditional barcode: "*It's pretty obvious that if you buy a RFID tag for 5 or 7 cents, that's plainly more costly than a half cent barcode"* (SBUS). The accelerating pace of RFID development over the past years was seen as critical in achieving significant reductions in the cost of equipment and widening adoption: *"We've seen some significant cost reductions over the past few years based on the fact that we've been able to standardize a protocol for RFID"* (SBUS). However, the cost of tags is seen as only one part, albeit a significant part, of the overall costs. Other costs are associated with the acquisition, installation, configuration, integration and running of RFID applications. As well as tags, RFID implementation involves the acquisitions of other equipment, including readers, and the associated IT infrastructure. Respondents emphasized that users focus less on the cost of tags, and more on the overall cost of ownership: "*I know from speaking to companies that they're starting to realize how much it costs to manage a barcode marked product.*" (SBUS). The magnitude of overall direct technology implementation costs varies depending on the type of RFID application: "*the cost of implementation depends on the process; it depends on the application and the amount of kit that's required, the number of read points, and if the* *hospital is requiring a supplier to tag, then who bears the costs? What's the supplier's relationship with the hospital? [What] will the supplier put the tags on? … Maybe it's only to track only goods coming into the hospital in which case you just need a couple of readers on the main delivery door"* (SBUK). Consequently, as improvements in RFID technology have driven down the costs of tags, other direct costs associated RFID equipment (such as readers) and the connected IT infrastructure (such as RFID software applications and related databases) have become much more of a concern to potential adopters.

4.2.6. Indirect implementation costs

Three types of indirect costs were mentioned by respondents: business process reengineering, planning, and management and communication costs. One technology vendor summarized all these implementation costs as follows: "*… so first you have to optimize the existing processes, existing workflow under the scope of the new technology … And then you can come in and deploy the new technology with pilot projects and optimize again. And optimization means more or less everything, not only the way people are working, but also the mindset. You have to inform people, the staff and the patients, about the new technology. If you fail to do so I think your pilot project will fail"* (TVG).

The implementation of RFID requires changes in existing business processes. As we noted in the discussion of benefits, to generate higher efficiencies and improve patient and staff safety hospitals need to go beyond simply automating existing processes and use RFID as a tool to change their internal processes. Changes in business processes are expensive and complex and need to be planned in advance. The business process change has to begin prior to RFID implementation: "*It's essential that, before you start an auto-pilot project on RFID,* *you have to optimize existing clinical processes. This means before you go into the hospital to implement the new technology and adapt it to existing processes, you have to optimize the existing processes. Otherwise it would optimize failure, it would optimize mismanagement"* (TVG). These optimization costs go beyond switching costs and business process reengineering costs to include planning costs, and human costs such as training, communication and coordination costs.

The downside of embarking on RFID adoption without taking into consideration the indirect costs was evident for most of our respondents. For example, the representative of one standardization body emphasized the need to assess workflows fully and to approach the implementation process strategically in order to avoid any additional complications and costs: *"Hospitals just want to use RF because it seems like a good idea. They just start buying equipment and they could end up with a real mess in their hands if they don't plan it properly"* (SBUS). Similarly, dealing proactively with user resistance was seen as critical during RFID implementation. This proactive approach requires hospitals to incur significant communication and training costs: "*I think the main problem is that the users, the clinical staff, don't know … the benefits this new technology can offer. They are not included fully in pilot projects, which means they are not asked: "'What could be the benefit for you, what could help your daily work, your workflow?'. So the industry may be failing to develop the technology to meet the needs of the users.* " (TVG).

Communications costs were emphasized as one of the most significant expenses that hospitals need to incur to support implementation of RFID solutions. Communicating a positive image of RFID to users and emphasizing the benefits of RFID for individual users, rather than the hospital as a whole, was perceived as a significant driver during implementation: *"If they know that it has something to do with their benefits then they have no problem with it ... It's all about the usage of the system and how well they're able to show the benefits"* (SBUS). A strong emphasis on the individual benefits that accrue to staff from the use of RFID is essential to alleviate their concerns about the potential invasion of privacy that RFID human tracking applications pose: "*a lot had to do with education and how the champions of these projects presented it to staff, … to emphasize the benefits that they would get from using the system*" (TVUS). For an increased chance of successful implementation it is also important to present RFID implementations as safe and future-oriented investments, rather than as a short-term or temporary solution: "*one thing I tell people is, try not to think of RF as a fancy bar code, but think of it as a highly mobile computer, because then you'll get a glimpse of where its going to go in the future"* (SBUS). Communicating a positive image of RFID is important because users' perceptions of RFID are critical for technology adoption. Good communication between the management and hospital staff can contribute to a positive image of the technology among involved parties: *"a lot has to do with education and how the champions of these projects are presenting them to staff*" (TVUS).

4.2.7. Ethical costs

Challenges associated with the adoption of RFID applications to track patients and staff, as opposed to tracking assets, are the potential risk to data security and the perception of invasion of privacy. Respondents referred to ethical concerns as arising from the improved technical functionalities of RFID systems and the lack of familiarity of users with the technology*: "Privacy and security [...] link to the issue of [...] reliability and robustness of RFID systems"* (RDP). Ethical concerns arise from improved RFID tag memory capacities and wider RFID reading ranges. These enable organizations to capture and manage large amounts of data about items or, in this case, humans that are being tracked. Ethical considerations have been emphasized as a source of resistance, particularly for tracking medical staff. The major danger respondents emphasized was that staff would misinterpret the purpose of RFID, and therefore would be reluctant to use it: *"if you're tracking staff, there are a number of questions: 'What are you doing with the data? Are you using it to know where staff are? Do you use it only using when the staff are in stressful situations?'. If they know that it is for their benefit, then they have no problem with it. [If] what you're doing is tracking how long a break a staff member took … then of course you get resistance"* (TVUS). Medical staff may feel that they are under pressure, that their privacy in everyday work situations is being invaded, and they are experiencing a sense of control and surveillance: "*nurses are afraid of the big brother effect: 'my employer is watching me, is controlling me'"* (TVG). To a lesser extent, the respondents also noted privacy concerns for patients, particularly with respect to the management of (often confidential) information obtained through RFID systems.

A range of solutions are being developed in response to these privacy concerns, including the possibility of providing the opportunity to disable RFID tags, limiting reading ranges, and providing password regulations for data access. Respondents were generally positive about addressing ethical issues: they were seen as not posing a significant stumbling block to future adoption: *"The other topics of privacy, data security and so on, they can all be* *solved, that's not the big problem."* (TVG). Although a concern, dealing with ethical issues was not being seen as a significant impediment to widespread adoption.

5. Discussion

The range of benefits and costs associated with the adoption of RFID by the early majority (as identified by the healthcare sector) is summarized in Table 5, and compared to the benefits and costs of early adopters (represented by the retailing and automotive sector). As can be seen in Table 5, there are notable differences in the magnitude of the various types of costs and benefits incurred by the two categories of adopters. These differences are discussed in depth in the rest of this section.

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5.1. Benefits

Respondents representing the early majority discussed RFID benefits primarily in terms of the indirect benefits associated with improved efficiency in a hospital's internal organization. They were clear about the possibility of reducing costs by eliminating waste, and from improvements in hospital performance due to the optimization of the hospital workflow and improved patient safety. Direct benefits related to cost savings from greater automation of what is currently manually intensive work, including savings through not having to hunt for or replace mislaid medical equipment and from reducing costs associated with regular maintenance checks (Curtin et al., 2007), were also mentioned. This is in line with previous work on RFID, which identified similar direct and indirect benefits associated with the adoption of RFID by early adopters (see Table 5). However, previous work on early adopter sectors emphasised direct benefits as the major benefits derived from RFID use (Bottani and Rizzi 2008; Lee and Ozer, 2007), while indirect benefits were generally mentioned as a possible (but not yet generally proven) outcomes (Lee and Ozer, 2007). Few studies mention indirect costs as relevant to early adopters (Bhattacharya et al., 2007; Hellstrom, 2009). In contrast, our work has found that direct benefits are seen as being less important than indirect benefits in driving RFID adoption by the early majority. This is in line with existing research on RFID adoption, which found that cost reductions (direct benefits) were not considered a benefit for healthcare; instead the focus was on indirect benefits in the form of reduced error rates and improved customer service (Lee and Shim, 2007). One explanation for the greater emphasis placed on indirect benefits by early majority adopters is that, as the technology matures and becomes more widely adopted throughout the user population, the direct benefits are taken for granted and indirect benefits are seen as driving the business case. Another possible explanation is that indirect benefits, in the form of increased efficiency of existing business processes and improved inter-organizational relationships, take longer to be realised. In contrast, direct benefits, such as savings through automation, happen earlier. Consequently, indirect benefits are realised only once an innovation has been in use for a longer period of time. This is in line with observations for electronic data interchange, where, in the early days, documented outcomes included mostly direct benefits such as reduced order lead lower inventory costs;

better accuracy in ordering, shipping, and receiving; and reductions in labour costs (Stern and Kaufman, 1985 cited in Hansen and Hill, 1989). Later studies identified the increasing importance of indirect benefits such as improved supply chain relationships (Chwelos et al., 2001). In line with studies of early adopters, the early majority represented in our data did not claim any strategic benefits associated with technology use. This may be because the RFID technology is still under development, and implementation is still patchy even within the adoption context of the early majority. Assessing strategic effects such as developing closer links with patients is difficult based solely on pilot implementations.

5.2. Costs

The research found evidence for both initiation and development costs. As technological applications have moved beyond early adopters, initiation costs have become more relevant. In contrast to previous research on early adopters, which found no evidence of initiation costs (Smart et al., 2010), our study found that potential early majority adopters looked both within and outside their industry for information about existing applications and best practice, incurring significant initiation cost in the search for information. The development costs, observed in previous research on early adopters (Smart et al., 2010), remain significant for the early majority because users are still involved in technology development. Our interviewees revealed that while technical standardization has settled around EPCglobal standards, the lack of "good practice" standardized RFID solutions meant that applications were being developed jointly by technology vendors and the early majority adopters involved in pilot implementations. Because of the lack of a "best practice" application, pilot implementations helped to make clear both the benefits (Angeles, 2005), and the costs involved in technology adoption in particular settings. Users participating in these pilots faced significant set-up costs, and, together with technology vendors, were supporting some of the development costs. Consequently, although the emphasis changed from technical standards development (for early adopters) to business application standards development (for early majority), potential adopters continued to collaborate with technology vendors in developing applications, thus incurring development costs. Similar situations, in which early adopters collaborate with technology developers during the early stages of technology diffusion, can be found during the development of a range of other process innovations, for example the development of the e-business applications during the early 2000 (such as the development of Covisint platform by the automotive industry, see Gerst and Bunduchi, 2005b). In these cases, the adopters incur high development costs due to their involvement in the development of business applications for a particular technology.

The lack of a standardized RFID application in the healthcare context also created significant uncertainties about the real costs and benefits involved in technology adoption. Because of these uncertainties, potential users faced increased costs of capital associated with investment in the technology. This affected both the early adopters and the early majority. However, in contrast to the situation encountered by early adopters, for the early majority technical standards had been largely agreed and were clearly understood. Consequently, while early adopters were faced with high costs of capital because of the uncertainty surrounding both the technical (Koh et al., 2006) and the application sides of the technology (Smart et al., 2010), the costs of capital incurred by the early majority arose primarily from the uncertainty arising from the lack of standardised business applications.

The concerns surrounding the lack of sufficient and appropriate technical standardization, which were voiced in previous work on RFID (Curtin et al., 2007), seemed to have been alleviated, reducing the associated cost of capital for the early majority adopters.

Switching costs emerged as significant for the early majority adopters who rely on older equipment; for these adopters RF interfaces may cause significant compatibility issues. In line with previous research on early adopters (Smart et al. 2010), compatibility with other existing technologies was also seen as an important source of switching costs for the early majority. However, unlike previous work on early adopters, for the early majority there were no concerns about the compatibility of current technological investments with future solutions. This is possibly because global technical RFID standards have been agreed. Switching costs are, however, likely to become more significant in the future as RFID technology moves beyond localized pilot applications within individual departments, and requires integration within and across different hospital IT systems. This potential future compatibility problem is particularly high in hospital environments, which tend to lack an overall, integrated and planned approach to technology adoption.

Direct and indirect implementation costs and ethical costs were all evident in the study. In line with recent research (Chao et al., 2007), our findings reveal that direct costs, including in the case of RFID the cost of tags, antennas, assembly and licensing costs, posed a significant challenge to adoption. Research on early adopters identified the direct costs of tags as one of the most significant costs associated with RFID adoption (Banks et al., 2007; Jones et al., 2005; Prater and Frazier, 2005; Wu et al., 2006). Our study shows that for the early majority, the emphasis is moving to the total cost of ownership, including the cost of tags, other equipment, and maintenance. The evidence for indirect costs was scarce in previous work on early adopters (Hellstrom, 2009; Smart et al., 2010). In contrast, in our work indirect costs emerge as the most significant category of costs for the early majority. The implementation of RFID applications requires both the integration of the new system into the existing hospital infrastructure, and costly changes in the organizations' operations through business process redesign (Curtin et al., 2007). The costs associated with business process redesign are significant for technology implementation within the context of early majority users; for example RFID applications are often used in hospitals as a means to change internal processes (Lee et al., 2008). Our study identified indirect costs associated with these internal business process changes, and communication and coordination costs associated with the implementation effort and planning, as the most significant costs associated with technology implementation in the organizational context of early majority. For process innovations such as information technologies, indirect costs tend to be more significant than direct costs (Love et al., 2005). It is therefore particularly important to understand the shift in emphasis from direct to indirect costs as process technologies diffuse. This understanding can help potential adopters to build the business case for investing, or not investing, in a particular technology.

In line with the observations for early adopters (Bhattacharya et al., 2007; Smart et al., 2010), our findings indicate that ethical costs continue to remain high for the early majority. Previous work on early adopters identified privacy concerns of consumers as the major contributor to ethical costs. We identified privacy concerns associated with staff, rather than with patients, as the most significant contributor to ethical costs for the early majority. Our findings confirm Curtin et al.'s (2007) argument, which indicates that tagging staff could be perceived as excessive oversight, with the potential to hamper the adoption of RFID. One reason for the focus on staff rather than patients for the early majority may be that as the technology diffuses, the need to facilitate organizational adoption becomes pressing. Because employees' resistance to adoption is one of the major obstacles to technology implementation, it is not surprising to find that major efforts are being made to alleviate these concerns. As ethics issues become more prominent for innovations other than RFID within the healthcare context (such as electronic patient records), and for RFID adoption within other contexts (such as retail), a detailed understanding of the ethical costs will become essential.

In line with previous work on early adopters (Smart et al., 2010), this study found no evidence that relational costs were a concern for the early majority. At the time of the study RFID adoption in hospitals had happened largely within single organizations. RFID projects were still largely pilot projects and/or are concentrated on developing the technology for use in one organization: widespread adoption had not yet taken place. The lack of evidence for relational costs is therefore unsurprising given this localized pattern of adoption.

6. Conclusions

This study has made several contributions to literature and to business practice. First, it has provided evidence that innovation costs and benefits vary as a technology evolves. By comparing the costs and benefits incurred by the early majority with the benefits and costs associated with early adopter sectors, the research has shown that the magnitude of innovation outcomes changes as the RFID technology diffuses. During the early stages of technology evolution, development costs, the costs of capital, ethical costs and simple direct implementation costs (in the form of the cost of tags) predominated (Smart et al, 2010). As the technology has become more mainstream, and a dominant design has emerged, the profile of costs has changed, with the emphasis being placed on initiation costs, on more holistic direct implementation costs, and in particular, on indirect implementation costs. A similar change in the emphasis of benefits was observed, with a shift from direct to indirect benefits being noticeable as the technology moved from early adopters to early majority. Future research is needed to assess whether these variations are also observed for other technologies, and how these patterns are reflected in the population of innovation adopters. Such a study would require a longitudinal design to examine the relationship between costs and likelihood of adoption during the different stages of a technology life cycle.

6.1. Limitations

This study has a number of limitations. First, a major limitation is a consequence of the choice of the research design, in particular the unit of analysis. The focus on industry-level, rather than organizational-level,, adoption has meant that the study does not take into consideration sectoral differences which may have affected the magnitude of costs and benefits. To address this shortcoming, future research should aim to identify a range of industries, beyond healthcare, that are early majority adopters of RFID technology. Qualitative case studies can be used to explore whether the pattern of costs and benefits identified here holds true across a range of industries.

Second, the qualitative research design, although appropriate at a stage when the technology is still evolving, precludes the generalisations of the findings to other application settings and/or other technologies. As the technology matures, a quantitative approach, coupled with case studies, would be appropriate to investigate the costs associated with RFID adoption across a range of different application settings. Further, a longitudinal study involving repeated data collection at different points in time to examine the adoption at organization level within different industries would enable further studies as the technology diffuses. This approach would offer the best (but also the most resource intensive) approach to studying the change in the magnitude of costs at both organizational- and industry-level, and would enable researchers to account for sectoral differences in the patterns of adoption.

Third, the study focuses on technology vendors. Future studies should include users in the sample, in order to broaden the perspectives on RFID implementation. In doing this, it will be important to consider the access and ethical issues associated with all studies carried out in the healthcare sector.

Fourth, the study does not take into consideration the different stages involved in technology implementation; instead innovation outcomes are assessed as resulting from technology use. However, research has shown that technology implementation involves different stages (Kwon and Zmud, 1987), and innovation benefits, for example, cannot be fully realised until "full implementation" (Klein and Sorra, 1996), or when the innovation is inofused throughout the organization (Zmud and Apple, 1992). Future research is required to expand the analysis of innovation outcomes to differentiate between the different stages involved in innovation implementation. Such research would need first to map the innovation outcomes onto the different implementation stages, and second to assess whether the outcomes at various points within the implementation process vary depending on the level of technology maturity. A roadmap detailing future research is shown in Table 6.

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Insert Table 6 about here

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6.2. Implications for theory

Despite its limitations, this study makes two important contributions to existing innovation literature. The first contribution is that, by demonstrating that the magnitudes of innovation outcomes vary depending on the innovation life cycle stage, the study helps to explain some of the lack of clarity about the outcomes of innovation in the implementation literature. In particular, it helps to explain some of the difficulties in assessing what represents a successful implementation (Linton, 2002; Meyer et al., 1996). Our findings suggest that as a technology moves between different stages, adopters experience different benefits and incur different costs. Consequently, what represents “successful implementation” depends on the stage of technology development. For example, for the implementation of emergent technologies, success needs to be assessed relative to transaction and production cost reduction (direct benefits). In contrast the implementation of more mature technologies needs to be evaluated in terms of the innovation’s impact on the efficiency of the organization’s internal operations and on the relationships that the organization develops with other supply chain actors (indirect benefits). Our study on the dynamics of innovation outcomes (in the form of benefits and costs) throughout the diffusion of the innovation parallels existing research that shows that the driving factors in adopting innovation also change as the innovation diffuses (Waarts et al., 2002). Together, such findings call for further research on the dynamics of innovation drivers and outcomes throughout the process of diffusion, moving beyond the single snapshot studies that seem to dominate process innovation adoption research.

Our results also indicate that differences in the magnitudes of innovation outcomes imply that different categories of benefits and costs play different roles in shaping the innovation adoption decision. To stimulate the adoption of particular innovations, organizations and/or policy makers will need to emphasise different benefits and/or develop different strategies to cope with the costs. For example, to stimulate the adoption of technologies in the early stages of development, policy makers may choose to emphasise the innovation's direct benefits, and will have to provide subsidies to reduce the costs of development and capital costs involved in technology adoption. In contrast, to stimulate the adoption of more mature technologies, greater efforts will need to be made to communicate information about indirect benefits and/or subsidies will need to be provided to reduce initiation and indirect implementation costs.

6.3. Implications for practice

The study has identified the perceptions of technology vendors of the benefits and costs associated with RFID adoption in healthcare. In the absence of a "good practice" study and of standardized applications, such perceptions are important in alleviating the uncertainties surrounding ROI in this context. Consequently, this study provides support to managers in identifying the expected benefits and costs associated with RFID adoptions, enabling them to build the business case for RFID investment.

For technology managers in general, the study has identified the profile of costs and benefits associated with technology adoption, and offered some indication of how this profile changes depending on the stage of technology evolution. For example, while direct benefits, development costs, and direct implementation costs are high during the early stages of technology development, indirect benefits, and initiation and indirect implementation costs take central stage as the technology evolves and diffuses through the early majority of adopters. As we demonstrated in the Discussion section, these changes in the magnitude of costs and benefits are not confined to RFID and are found for other technological process innovations. Therefore, technology managers can be helped both by understanding the underlying principles of costs and benefits associated with technology innovation, and the specific way in which these costs and benefits are manifest in the case of RFID technology. This understanding enables a clearer calculation of the ROI both for RFID applications and for technological process innovations in general, and focuses management attention on identifying the relevant costs and benefits depending on the maturity of the technology. Existing research shows that important elements of the cost – benefit equations are often not taken into consideration prior to technology adoption, leading to incomplete analysis (Hellstrom, 2009) and potentially hampering technology diffusion.

References

Allen, D., Colligan, D., Finnie, A., Kern, T. 2000. Trust, power and interorganizational information systems: the case of the electronic trading system TransLease. Information Systems Journal. 10(1), 21 - 40.

Anderson, P., Tushman, M.L. 1990. Technological discontinuities and dominant design: A cyclical model of technological change. Administrative Science Quarterly. 35(4), 604-633.

Attewell, P. 1992. Technology diffusion and organizational learning: The case of business computing. Organization Science. 3(1), 1-19.

Banks, J., Pachano, M., Thompson, L., Hanny, D., 2007. RFID Applied. Wiley & Sons, New Jersey.

Bhattacharya, M., Chu, C-H, Mullen, T. 2007. RFID implementation in retail industry: Current status, issues and challenges. In Proceedings of the Decision Science Institute Conference, Phoenix, 1-23.

Bhattacharya, M., Chu, C-H, Mullen, T. 2008. A comparative analysis of RFID adoption in retail and manufacturing sectors. In Proceedings of the IEEE International Conference on RFID, Las Vegas, April 16-17, 241-249.

Bottani, E., Rizzi, A, 2008. Economical assessment of the impact of RFID technology and EPC system on the fast-moving consumer goods supply chain. International Journal of Production Economics. 112(2), 548-569.

Bunduchi, R., Smart, A. 2010. Process innovation costs in supply networks: A synthesis, International Journal of Management Reviews. 12(4), 365-383.

Carney, B. M. 2001. Breaches of confidentiality and the Electronic Community Health Record: Challenges for healthcare organizations and the community. HEC Forum. 13(2), 138-147.

Chao, C-C., Yang, J-M., Jen, W-Y. 2007. Determining technology trends and forecasts of RFID by a historical review and bibliometric analysis from 1991 to 2005. Technovation. 27(5), 268-279.

Chwelos, P., Benbasat, I., Dexter, A.S. 2001. Research report: Empirical test of an EDI adoption model. Information Systems Research. 12(3), 304-21.

Collins, J. 2005. Health care sees safety in RFID. RFID Journal. Nov. 23, available at: http://www.rfidjournal.com/article/articleview/2005/1/1/

Creswell, J.W., 1994. Research Design. Qualitative & Quantitative Approaches, Sage Publications, Thousand Oaks.

Cunningham, C. and Tynan, C. 1993. Electronic trading, inter-organizational systems and the nature of buyer-seller relationships: the need for a network perspective. International Journal of Information Management. 13(1), 3-28.

Curtin, J., Kauffman, R.J., Riggins, F.J., 2007. Making the 'most' out of RFID technology: A research agenda for the study of the adoption, use and impacts of RFID. Information Technology and Management. 8(2), 1573-7669.

Damanpour, F. and Schneider, M., 2006. Phases of the adoption of innovation in organizations: The effect of environment, organization and top managers. British Journal of Management. 17(3), 215-236.

Damanpour, F., Wischnevsky, J.D. 2006. Research on innovation in organizations: Distinguishing innovation-generating from innovation-adopting organizations. Journal of Engineering Technology Management. 23(4), 269-291.

Davis, F.D. 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly. 13(3), 319-340.

Dew, N. 2006. Incommensurate technological paradigms? Quarrelling in the RFID industry. Industrial and Corporate Change. 15(5), 785-810.

Dew, N., Read, S., 2007. The more we get together: coordinating network externality product introduction in the RFID industry. Technovation. 27(10), 569-581.

Edquist, C., Hommen, L., McKelvey, M. 2001. Innovation and employment: process versus product innovation. Edward Elgar Publishing Limited, Cheltenham.

van den Ende, J., Kemp, R. 1999. Technological transformations in history: how the computer regime grew out of existing computing regimes. Research Policy. 28(8). 833-851.

Farrell, J., Saloner, G. (1985). Standardization, Compatibility, and Innovation. The Rand Journal of Economics. 16, 70 - 83.

Farrell, J., Shapiro, C. (1988). Dynamic Competition with Switching Costs. The Rand Journal of Economics. 19(1), 123 - 137.

Fichman, R. 1992. Information technology diffusion: A review of empirical research. In Proceedings of the 13th International Conference on Information Systems, December, Dallas, 195-206.

Forman, C. 2005. The corporate digital divide: Determinants of Internet adoption. Management Science. 51(4), 641-654.

Garfinkel, S., Holtzman, H. 2005. Understanding RFID Technology, in: Garfinkel, S.; Rosenberg, B. (Eds.), RFID. Addison-Wesley, Upper Saddle River, pp. 15–36.

Geels, F.W. 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Research Policy. 31(8-9), 1257-1274.

Genus, A., Coles, A-M. 2008. Rethinking the multi-level perspective of technological transitions. Research Policy. 37(9), 1436-1445.

Gerst M., Bunduchi R. 2005a. Challenges in the adoption of RFID standards, in: Santucci, G., Frederix, F. (Eds.), Strengthening Competitiveness through Production Networks. Luxembourg European Communities, pp. 81-90.

Gerst M., Bunduchi R. 2005b. Shaping IT standardisation in the automotive industry - the role of power in driving portal standardisation. Electronic Markets, 15(4), 335-343.

Geroski, P.A., 2000. Models of technology diffusion. Research Policy. 29(4-5), 603-625.

Gupta, A., Kauffman, R.J., Wu, A.P. 2008. Do Firm R&D Investments Drive Decisions to Join? On the Value of Standard-Setting Organizations in the Consumer Electronics Industry, In Proceedings of 41st HICSS Conference, Hawaii, January 7-10.

Hansen, J.V. and Hill, N.C. 1989 Control and audit of Electronic Data Interchange. MIS Quarterly. 13(4), 403-413.

Hart, P. J., Saunders, C. S. 1998. Emerging Electronic Partnerships: Antecedents and Dimensions of EDI Use from the Supplier's Perspective. Journal of Management Information Systems. 14(4), 87 - 111.

Hellstrom, D. 2009. The cost and process of implementing RFID technology to manage and control returnable transport items. International Journal of Logistics Research and Applications. 12(1), 1-21.

Hollenstein, H., Woerter, M. 2008. Inter- and intra-firm diffusion of technology: The example of E-commerce. An analysis based on Swiss firm-level data. Research Policy. 37(3), 545-564.

Irani, Z., Ezingeard, J.-N., Grieve, R. J. 1997) Integrating the costs of a manufacturing IT/IS infrastructure into the investment decision-making process. Technovation. 17(11-12), 695-706.

Iacovou, C.L., Bensabat, I., Dexter, A.S., 1995. Electronic data interchange and small organizations: adoption and impact of technology. MIS Quarterly. 19, 465-485.

Jakobs, K., 2009. Information Communication Technologies Standardization for E-Business Sectors: Integrating Supply and Demand Factors, Information Science Reference, Hershey.

Jimenez-Martinez, J., Polo-Redondo, Y., 2004. The influence of EDI adoption over its perceived benefits. Technovation. 24, 73-79.

Johnston, H. R., Vitale, M. R. 1988. Creating Competitive Advantage with Interorganizational Information Systems. MIS Quarterly. 12, 153-165.

Jones, P., Clarke-Hill, C., Hillier, D., Comfort, D., 2005. The benefits, challenges and impacts of radio frequency identification technologies (RFID) for retailers in the UK. Marketing Intelligence & Planning. 23(4), 395-402.

Katz, J. E., Rice, R. E., 2008. Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology. Journal of Communication. 35(2), 210-214.

Kelly, E.P., Erickson, G.S. 2005. RFID tags: commercial applications v. privacy rights. Industrial Management + Data Systems. 105 (5/6), 703-713.

Klein, K. J., Sorra, J. S., 1996. The challenges of innovation implementation. The Academy of Management Review. 21(4), 1055-1080.

Klemperer, P. (1995). Competition when consumers have switching costs: An overview with applications to industrial organization, macroeconomics, and international trade. The Review of Economic Studies. 62(4), 515 - 539.

Koh, C.E., Kim, H.J., Kim, E.Y. 2006. The impact of RFID in retail industry: Issues and critical success factors. Journal of Shopping Research. 13(1), 101-117.

Kuo, C. H. and Chen, H. G., 2008. The critical issues about deploying RFID in healthcare industry by service perspective, in: Hawaii International Conference on System Science, pp. 111.

Kumar, K., van Dissel, H.G. 1996. Sustainable collaboration: managing conflict and cooperation in interorganizational systems. MIS Quarterly. 20(3), 279-300.

Kwon, T.H. , Zmud, R.W. 1987. Unifying the fragmented models of information systems implementation, in: Borland, R.J., Hirscheim, R.A. (Eds), Critical issues in Information Systems Research. John Wiley, Chichester, pp. 227-251.

Lee, C-P., Shim, J.P. 2007. An exploratory study of radio frequency identification (RFID) adoption in the healthcare industry. European Journal of Information Systems. 1(6), 712-724.

Lee, H., Ozer, O., 2007. Unlocking the Value of RFID. Production and Operations Management. 16(1), 40-64.

Lee, L.S., Fiedler, K.D., Smith, J.S., 2008. Radio frequency identification (RFID) implementation in the service sector: A customer-facing diffusion model. International Journal of Production Economics. 112(2), 587-600.

Leonard-Barton, D. 1990. A dual methodology for case-studies: Synergistic use of a longitudinal single site with replicated multiple sites. Organization Science. 1(3), 248-266.

Linton, J. D. 2002. Implementation research: state of the art and future directions. Technovation. 22(2), 65-79.

Love, P.E.D., Irani, Z., Standing, C., Lin, C. and Burn, J.M. 2005. The enigma of evaluation: benefits, costs and risks of IT in Australian small-medium-sized enterprises. Information Management. 42(7), 947-964

O'Connor, E. J., Parsons, C. K., Liden, R. C., Herold, D. M. 1990. Implementing new technology: management issues and opportunities. Journal of High Technology Management Research, 1(1), 69-89.

OECD. 2001. Cities & regions in the new digital economy. OECD Publications, Paris.

Öztaysi, B., Baysan, S., Akpinar, F. 2009 Radio frequency identification (RFID) in hospitality. Technovation. 29 (9), 618-624.

Markus, M. L. 2000. Toward an integrated theory of IT-related risk control. In Baskerville, R., Stage, J. and DeGross, J. I. (eds.) Organizational and social perspectives on information technology. Kluwer Academic Publishers, Boston.

Mata, F. J., Fuerst, W. L., Barney, J. B. 1995. Information technology and sustained competitive advantage: A resource-based analysis. MIS Quarterly. 19(4), 487 - 505.

Melville, N., Ramirez, R. 2008. Information technology innovation diffusion: an information requirements paradigm. Information Systems Journal. 18(3), 247-273.

Meyer, A.D., Goes, J.B., 1988. Organizational assimilation of innovations: A multilevel contextual analysis. Academy of Management, 31(4), 897-923.

Meyers, R. W., Sivakumar, K., Nakata, C. 1999. Implementation of industrial process innovations: Factors, effects, and marketing implications. Journal of Product Innovation Management. 16(3), 295-311

Miles, M. B., Huberman, A. M., 1994. Qualitative Data Analysis: An Expanded Sourcebook. Sage Publications, Thousand Oaks.

Mukhopadhyay, T., Kekre, S. 2002. Strategic and operational benefits of electronic integration in B2B procurement processes. Management Science, 48(10)

Mukhopadhyay, T., Kekre, S., Kalathur, S. 1996. Business value of information technology: A study of Electronic Data Interchange. MIS Quarterly. 19(2), 137-156.

Nagy, P., George, I., Berstein, W., Caban, J., Klein, R., Merzich, R., Park, A., 2006. Radio Frequency Identification systems Technology in the Surgical Setting. Surgical Innovation. 13(1), 61-67.

Ngwenyama, O. K., Lee, A. S., 1997. Communication Richness in Electronic Mail: Critical Social Theory and the Contextuality of Meaning. MIS Quarterly. 21(2), 145-167.

Patton, M. Q., 1987. How to use qualitative methods in evaluation. Sage, Newbury Park, CA.

Payne, S., 2000, Interview in Qualitative Research, in: Memon, A., Bull, R. (Eds.), Handbook of the Psychology of Interviewing. John Wiley & Sons, Chichester, pp. 89-102.

Powell, T. C., Dent-Micallef, A. 1997. Information technology as competitive advantage: The role of human, business, and technology resources. Strategic Management Journal. 18(5), 375 - 405.

Prater, E., Frazier, G. 2005. Future impacts of RFIS on e-supply chains in grocery retailing. Supply Chain Management: An International Journal. 10(2), 135-142.

Premkumar, G., Ramamurthy, K., Nilakanta, S. 1994. Implementation of Electronic Data Interchange: An innovaton diffusion perspective. Journal of Management Information Systems. 11(2), 157-186.

Reichstein, T., Salter, A. 2006. Investigating the sources of process innovation among UK manufacturing firms. Industrial and Corporate change, 15(4), 653-682.

Remenyi, D., Williams, B., Money, A., Swartz, E. 2000. Doing Research in Business and Management. Sage Publications, London.

Repenning, N. P. 2002. A simulation-based approach to understanding the dynamics of innovation implementation. Organization Science. 13(2), 109-127.

Rogers, E.M. 1995. Diffusion of innovation. Free Press, New York.

Russell, S., Williams, R., 2002. Social Shaping of Technology: Frameworks, Findings and Implications for Policy With Glossary of Social Shaping Concepts, in: Sorensen, K., H., Williams, R. (Eds.), Shaping Technology, Guiding Policy. Edward Elgar, Chetlenham, pp. 37-132.

Ryan, S. D., Harrison, D. A. 2000. Considering social subsystem costs and benefits in information technology investment decisions: A view from the field on anticipated payoffs. Journal of Management Information Systems. 16(4), 11 - 38.

Schmitt, P., Michahelles, F. 2009. Status of RFID/EPC adoption. Auto-ID Labs White Paper WP-BIZAPP-048.

Schmitt, P., Thiesse, F., Fleisch, E. 2007. Adoption and diffusion of RFID technology in the automotive industry. Auto-ID Labs White Paper WP-BIZAPP-041 (also In Proceedings of 15th European Conference on Information Systems, E-DIGIT by SIGADIT, 2007, St Gallen, Switzerland).

Sharma, A., Citurs, A. 2005. Drivers and rationales in RFID adoption and post adoption integration: An integrative perspective on IOS adoption. In DIGIT 2005 Proceedings, paper 4, pp. 22.

Smart, A.U., Bunduchi, R., Gerst, M. 2010. The costs of interorganizational IT innovation adoption: RFID technologies in supply networks, International Journal of Operations and Production Management. 30(4), 423-447.

Stake, R. E. 1995. The Art of Case Study Research. Sage Publications, Thousand Oaks.

Stern, L., Kaufman, P. 1985. EDI in selected consumer good industries: an interorganizational perspective. Marketing in an Electronic Age. Harvard Business School Press. Boston.

Subramani, M. 2004. How do suppliers benefit from information technology use in supply chain relationships? MIS Quarterly, 28(1), 45-73.

Tang, M.-J., Zannetos, Z. S. 1992. Competition Under Continuous Technological Change. Managerial and Decision Economics. 13(2), 135 - 148.

The Economist. 2007. Case history: Bright prospects, The Economist Technology Quarterly, March 10th, 20-23.

Thompson, V., 1965. Bureaucracy and Innovation. Administrative Science Quarterly. 10(1), 1 - 20.

Tidd, J., Bessant, J., Pavitt, K. 2005. Managing Innovation: Integrating technological, market and organizational change. Chichester: John Wiley and Sons.

Tzeng, S-F., Chen, W-H., Pai, F-Y., 2008. Evaluating the business value of RFID: Evidence from five case studies. International Journal of Production Economics. 112(2), 601-613.

Utterback, J.M. 1974. Innovation in industry and the diffusion of technology. Science. 183(4125), 620-626.

Utterback, J.M., Abernathy, W.J., 1975. A Dynamic Model of Process and Product Innovation. Omega, International Journal of Management Science, 3(6), 639-656.

Waarts, E., van Everdingen, Y.M., van Hillegersberg, J. 2002. The dynamics of factors affecting the adoption of innovations. Journal of Product Innovation Management. 19(6), 412-423.

Wang, S., Chen, W., Ong, C., Liu, L., Chuang, Y., 2006. RFID applications in hospitals: a case study on a demonstration RFID project in a Taiwan hospital, in: Proceedings of the 39th Hawaii International Conference on System Sciences, pp. 184.

Weber, M.M., Kantamneni, S.P., 2002. POS and EDI in retailing: an examination of underlying benefits and barriers. Supply Chain Management. 7(5), 311-317.

Weick, K.E., 1974. Middle range theories of social systems. Behavioural Science. 19(6), 357-367.

Wu, N.C., Nystrom, M.A., Lin, T.R., Yu, H.C., 2006. Challenges to global RFID adoption. Technovation. 26(12), 1317-1323.

Yin, R. K., 1994. Case Study Research. Design and Methods. Sage Publication, Thousands Oaks.

Zmud, R.W., Apple, L.E., 1992. Measuring technology incorporation/inofusion. Journal of Product Innovation Management. 9(2), 148-155.

Zhu, K., Kraemer, K.L., Gurbaxani, V., Xu, S. 2006. Migration to open-standard interorganizational systems: Network effects, switching costs, and path dependency. MIS Quarterly., 30(3), 515-539.

Tables

Table 1. Benefits associated with process innovation adoption (adapted from Bunduchi and Smart, 2010)

Types of benefits	*Explanation*
Direct benefits	Based on the electronic transmission / handling of information and related to transaction and production costs savings through document handling
Indirect benefits	Related to improve efficiency in the firm's internal organization and changes in relationships with other supply chain members that have adopted the innovation
Strategic Benefits	Related to indirect benefits: result from the changes in the relationships with other supply chain members that use the innovation and generally refer to the ability to forge closer business links with these other users

Table 2. Costs associated with process innovation adoption (adapted from Bunduchi and Smart, 2010; Smart et al, 2010)

Types of costs	*Explanation*
Development costs (incurred by developers)	Costs associated with participation in the elaboration of a new technology. Include (1) the internal costs associated with internal R&D costs involved in in-house development; and (2) the external costs associated with participation and negotiation costs associated with the involvement in collaborative arrangements.
Initiation costs(incurred by acquirers)	Costs associated with building awareness about a new innovation
Switching costs	Compatibility costs arising from the need for compatibility with existing assets when changing from an existing technology to a new technology. Include (1) the costs associated with the complementary technological resources, e.g. costs associated with incumbent software and hardware; and (2) the costs associated with complementary organizational resources, e.g. changing the existing capabilities

	in marketing, service or distribution.
Capital cost	Costs associated with the uncertainty of investment in innovation. Include (1) the costs associated with technology uncertainties such as financial risks that the benefits are overestimated and/or costs were underestimated or the technical risk that the delivered technical performance is below what was anticipated, and results from a technology being immature, poorly understood, unreliable, obsolete or unstable; and (2) the costs associated with market uncertainties such as the risks associated with negative reactions by customers, competitors, technology suppliers, the general public and/or other potential stakeholders.
Implementation costs	The costs associated with acquiring and implementing an interorganizational process innovation include: (1) Direct implementation costs include initial hardware, software and installation costs; installation and configuration costs, security costs and maintenance costs as well as any unexpected hardware and software costs (2) Indirect implementation costs include (a) organizational costs associated with losses in organizational productivity; strains on organizational resources; business process reengineering; organizational restructuring and (b) human costs in terms of the time and resources expended by managers and operators in getting the system to work; systems support activities; training costs; changes in salaries (such as pay increases based on improved employee flexibility); and the resources required to deal with the consequences of staff turnover
Relational costs	Costs associated with the relational context in which the innovation is implemented, in particular the cost associated with lack of trust between supply network partners leading to ill feelings, resentment, tension, conflicts and withdrawal between innovation adopters.
Ethical costs	Costs associated with (1) privacy concerns and (2) health concerns regarding the use of technology

Table 3. List of respondents

Company	**Organization's activities**	**Respondent's responsibilities**

RDP	R&D aimed at the improvement of government policy	Member of the Information Policy and Economics Team
SBUK	UK based global standards development	Responsible for NHS-based projects and research
SBUS	U.S. based global standards development body for RFID	Responsible for the pharmaceutical and medical devices area
TVG	Innovation technologies and quality assurance in health care	Responsible for informing potential users about information technology and potential business opportunities
TVUS	Provider of RFID unified asset visibility solutions	Manager of the Industry Solutions Team.

Table 4. Hospital RFID applications and benefits

Main functionality	**RFID application**	**Description**	**Benefits**
Inventory management	Asset tracking	Track (generally high value) medical equipment	Reduce inventory costs by (1) losing fewer items; (2) holding lower inventories; (3) increasing efficiency by reducing the time staff spends tracing assets
Change internal business processes	Equipment maintenance	Tag equipment throughout the hospital to provide information such as equipment location and status and maintenance schedule.	Patient safety Compliance with regulatory requirements Increase efficiencies by automating maintenance tracking
	Condition monitoring	Use RFID sensors and related technologies to monitor temperature, humidity and motion of medical assets	Patient safety Reduce inventory costs by reducing waste Increase efficiency by automating monitoring

	Patient and staff safety	Monitor at risk patients, including Alzheimer's, dementia, and trauma patients	Patient and staff safety
	Workflow and resource management	Track the location and status of patients, physicians, available rooms and key clinical equipment in departments (OR / ER)	Increase efficiency by optimizing workflow

Table 5. Benefits and costs of early adopters versus early majority of users

Benefits and Costs	**Early adopters (previous research)**	**Early majority (this research)**
	BENEFITS	
Direct benefits	Significant, in the form of reduced labour and inventory handling costs (Curtin et al. 2005; Jones et al. 2005; Lee and Ozer, 2007)	Mentioned in the form of cost savings due to automation of what is currently manual work, including savings through avoiding lost medical equipment and reducing costs associated with regular maintenance checks
Indirect benefits	Potential for (i) making it easier to find misplaced items; (ii) reducing shrinkage from theft; and (iii) reducing transaction errors overall increasing efficiency (Lee and Ozer, 2007) Potential for improved customer relationships by increasing customer satisfaction and improved customer insight (Sharma and Citurs, 2005)	Emphasized in the form of (i) cost reductions owing to the elimination of waste and (ii) improvements in hospital performance from (a) optimization of the hospital workflow and (b) changes in the relationships with patients owing to improved patient safety
Strategic Benefits	No evidence (Hellstrom, 2009)	No evidence
	COSTS	
Development	Significant – associated with	Still important in the form of co-

costs	participation in technology standardization organizations (Smart et al., 2010)	development of applications together with technology vendors during implementation
Initiation costs	No evidence (Smart et al., 2010)	Significant, owing to the lack of information about the benefits and costs associated with RFID adoption
Switching costs	High primarily owing to the need for technical compatibility with future RFID technologies, and with existing technologies (Smart et al., 2010)	Arise because of the need for integration with existing technologies
Capital cost	Significant – arise because of high uncertainty of technology (Koh et al., 2006) in particular due to technological immaturity, lack of standards and problems with data accuracy (Smart et al., 2010), and lack of standardized RFID application (Gerst and Bunduchi, 2005a; Smart et al., 2010)	Lack of standardized application continues to create uncertainty
Direct implementation costs	The cost of tags is the most significant cost associated with RFID adoption (Banks et al., 2007; Jones et al., 2005; Prater and Frazier, 2005; Smart et al., 2010; Wu et al., 2006) Other direct costs mentioned include savings in labour and inventory costs (Bottani and Rizzi, 2008), hardware and software installation costs, reader equipment and maintenance costs (Hellstrom, 2009; Schmitt and Michahelles, 2009)	Focus on total cost of ownership including all RFID equipment and maintenance, moving beyond the cost of tags
Indirect implementation costs	Little evidence, as most applications are localized, pilot applications (Smart et al., 2010). Software integration costs are occasionally mentioned (Hellstrom, 2009; Schmitt and Michahelles,	The costs associated with internal business process changes, the communication and coordination costs associated with the implementation effort and the planning costs emerge as the

	2009)	most significant costs
Relational costs	No evidence, as most applications are pilot applications within organizational boundaries (Smart et al., 2010)	No evidence, as most application are within organizational borders
Ethical costs	Significant evidence for concerns about consumers' privacy (Bhattacharya et al., 2007; Kelly and Erickson, 2005; Smart et al., 2010)	Evidence for concerns about staff privacy

Table 6. Roadmap for future research

Extension of findings to …	**Research design**
Other industries	(1) Comparative case studies of different industries involved in RFID adoption at the early majority stage (to identify whether the pattern of cost and benefits holds) (2) Longitudinal survey of RFID technology adoption at organization level across different industries and across time (to clarify the role of organizational / sectoral / stage of diffusion differences in shaping the magnitude of costs)
Other organizational innovation stages	Comparative case studies of technology adoption at organizational level measuring the magnitude of costs and benefits as the technology diffuses throughout the organization
Other technologies	Historical / longitudinal case studies of technology adoption and diffusion, focusing on identifying the reported costs and benefits at different stages of diffusion